Shrapnel Hazard Testing

OBERON

INTRODUCTION

Over the past several years, personal protective equipment (PPE) has been developed to protect workers from the intense heat energy of an electric arc flash event. Oberon arc flash suits including hoods and hood shield windows are available with heat protection levels up to 100 cal/cm^2. However, there is increasing concern among some members of the NFPA 70E Technical Committee regarding potential hazards other than heat exposure that are also part of an electric arc event, e.g. shrapnel, pressure waves and high sound levels. The NFPA 70E Technical Committee elected to limit its Hazard/Risk Category exposure levels to 40 cal/cm^2 in the proposed 2004 edition until a better understanding of these additional arc flash hazards is achieved. Oberon and DuPont have conducted limited ballistic testing for the better understand the performance of Oberon arc flash product performance against shrapnel hazards.

ARC FLASH EVENT DESCRIPTION

An electric arc flash event consists of a complicated series of hazards primarily originating from the nearly instantaneous generation of an atmospheric plasma. These hazards include a radiant heat exposure, a pressure or “shock” wave, an excessive noise exposure, molten metal splatter (from the plasma erosion of the conductors and nearby materials), and ejection of projectiles or bits of “shrapnel” accelerated by the explosive force of the plasma formation.

ARC FLASH EVENT SHRAPNEL GENERATION

There is anecdotal evidence that electrical workers have been injured by projectiles or shrapnel emitted from an arc flash event. The nature of the shrapnel hazard has not been quantified or related to arc flash parameters, and it is likely that the projectile mass, shape and velocity of shrapnel emitted from an arc event is dependent on the type of equipment involved, the failure mode, and the energy available. It seems logical that the same parameter that has primary influence on the pressure wave, i.e., the arc current level, would be expected to influence the energy available to accelerate shrapnel to ballistic velocities. There may also be an influence from the electro-magnetic fields acting on the projectile.

SHRAPNEL HAZARD VERSUS HEAT EXPOSURE

Because the shrapnel hazard is very likely related to fault current and the explosive forces during the first half cycle of an arc flash event, and heat exposure is related to both fault current and the duration of the arc flash, the hazard analysis used for heat exposure cannot be applied to the shrapnel hazard. For instance, it is possible to have a very short arc flash duration of a half cycle but with a high fault current of 100kA that could generate a shrapnel hazard, but these arc parameters would create a relatively low heat exposure. Conversely, we could have a long duration arc flash event of 60 cycles (1 second) with a low fault current of 8kA that would be much less likely to produce a significant shrapnel hazard but would create a very high heat exposure. Consequently, the shrapnel hazard cannot “piggyback onto the hazard analysis used for heat exposure.

SHRAPNEL HAZARD OBERON PPE TESTING

Although it is not possible to accurately quantify the shrapnel hazard, i.e. we can’t predict the projectile mass, shape, temperature, and velocity for each potential arc flash event, it is possible to measure the shrapnel or ballistic resistance of arc flash fabric systems and hood shield windows to standardized ballistic threats. Oberon has utilized standard fragment testing technology developed to evaluate body armor and helmets for military personnel to evaluate Oberon arc flash protective products. Competitive arc flash PPE suppliers, at this point in time, have not performed ballistic testing of their arc flash PPE.

Arc flash hood windows and face shields must meet the projectile impact requirements of ANSI Z87.1. This standard specifies that a 0.25 inch steel ball projectile must not penetrate the shield window or face shield at a velocity of 300 feet/second. It does not consider irregularly shaped projectiles or ballistic velocities (generally considered to start at approximately 500 to 600 feet/second) that may accompany an arc flash event. Ballistic testing is usually conducted using two different projectiles: bullets that, in most cases, do not have sharp edges, and fragments that generally do have sharp edges. Since projectiles emitted from an arc flash event would tend to be irregular in shape and likely to have sharp edges, testing of arc flash PPE was conducted using fragments instead of bullets.

Table 1 provides ballistic test results for 100 cal/cm^2 rated hood shield windows. Each hood shield window was molded from polycarbonate material. Ballistic V_{50} results are provided for a test fragment diameter of 0.22 inches. V_{50} is the velocity at which 50% of the projectiles penetrate the target specimen.

Table 1: Ballistic V_{50} Results Hood Shield Windows

100 cal/cm^2 Arc Rated Hood Shield Window Specimen	Fragment Caliber or Diameter inches	V_{50} feet/second
Arc Rated Polycarbonate Window	0.22	377
Arc Rated Polycarbonate with Clear Polycarbonate Backup Window	0.22	856

V_{50} is the velocity at which 50% of the projectiles penetrate the target specimen.

Table 2 provides ballistic test results for the Oberon ARC100 and ARC100B inherently FR fabric systems and a competitive Flame Retardant Treated (FRT) cotton fabric system with an arc rating of 100 cal/cm^2. Ballistic V_{50} results are provided for a test fragment caliber (diameter) of 0.22 and 0.308 inches. These V_{50} results illustrate the expected benefit due to the additional, tightly woven, Kevlar® para-aramid “ballistic” fabric layer in the

ARC100B system. Even though the competitive FRT cotton arc flash suit fabric system is more than 60% heavier than the standard ARC100 fabrics system, the competitive FRT fabric system provides less ballistic protection than the standard Oberon ARC100 fabric system. The poorer showing of the much heavier FRT cotton specimen is expected due to the significantly lower fabric tensile strength of FRT cotton compared to the inherently FR Oberon materials.

Table 2. Ballistic V_{50} Results for Arc Rated

Fabric Systems 100 cal/cm^2 Arc Rated Layer Fabric System Specimen	Fabric System Weight (oz/yd^2)	V_{50} feet/second (Fragment Caliber/Diam. inches)
ARC100B System with Kevlar® Ballistic Layer	27	789 (0.308)
ARC100 Fabric System No Ballistic Layer	26	627 (0.308)
Flame Retardant Treated Cotton No Ballistic Layer	42	610 (0.22)
ARC100 Fabric System No Ballistic Layer	26	690 (0.22)